Iowa State University
Digital Repository

Statistics Publications | Statistics

7-1988

An Interactive Probability Plotting Program

Karen L. Jensen
Iowa State University

Stephen V. Crowder
Corning Glass Works

Stephen B. Vardeman
Iowa State University, vardeman@iastate.edu

Follow this and additional works at: https://lib.dr.iastate.edu/stat_las_pubs

Part of the Statistics and Probability Commons

The complete bibliographic information for this item can be found at https://lib.dr.iastate.edu/stat_las_pubs/148. For information on how to cite this item, please visit http://lib.dr.iastate.edu/howtocite.html.

This Article is brought to you for free and open access by the Statistics at Iowa State University Digital Repository. It has been accepted for inclusion in Statistics Publications by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.

An Interactive Probability Plotting Program

Abstract

An interactive FORTRAN program is presented which allows the user to produce probability plots (theoretical quantile-quantile plots) for an input data set based on several types of theoretical distributions. The program provides normal, two-parameter lognormal, three-parameter lognormal, right-tail half-normal, left-tail half-normal, exponential, two-parameter Weibull, and three-parameter Weibull plots. The present version of the program allows data entry and editing from the keyboard (not from stored files) and will accept up to 100 data values. This upper limit could easily be modified.

Keywords

Exponential Distribution, Half-Normal Distribution, Lognormal Distribution, Normal Distribution, Probability Plotting, Weibull Distribution

Disciplines

Statistics and Probability

Comments

This article is published as Jensen, Karen L., Stephen V. Crowder, and Stephen B. Vardeman. "An interactive probability plotting program." *Journal of Quality Technology* 20, no. 3 (1988): 196-210. DOI: 10.1080/00224065.1988.11979107.

Rights

Reprinted with permission from Journal of Quality Technology (c) 1988 ASQ, www.asq.org

This article is available at Iowa State University Digital Repository: https://lib.dr.iastate.edu/stat_las_pubs/148

An Interactive Probability Plotting Program

KAREN L. JENSEN

Iowa State University, Ames, IA 50011

STEPHEN V. CROWDER

Corning Glass Works, Corning, NY 14831

STEPHEN B. VARDEMAN

Iowa State University, Ames, IA 50011

An interactive FORTRAN program is presented which allows the user to produce probability plots (theoretical quantile-quantile plots) for an input data set based on several types of theoretical distributions. The program provides normal, two-parameter lognormal, three-parameter lognormal, right-tail half-normal, left-tail half-normal, exponential, two-parameter Weibull, and three-parameter Weibull plots. The present version of the program allows data entry and editing from the keyboard (not from stored files) and will accept up to 100 data values. This upper limit could easily be modified.

Introduction

PROBABILITY plotting is a graphical method used to investigate whether an assumed statistical model gives an adequate fit to a set of data. A probability plot helps an investigator to assess how well a given theoretical distribution fits the data and allows one to estimate distribution parameters.

A probability plot is produced by plotting the data quantiles against the corresponding quantiles of the given theoretical distribution. (For this reason, these plots are sometimes referred to as "theoretical quantile-quantile plots.") A linear pattern of points indicates agreement between the data distribution and the theoretical distribution. Nonlinear patterns indicate that the assumed model is not a reasonable representation of the data. Chambers, Cleveland, Kleiner, and Tukey (1983) give guidelines for interpreting patterns in probability plots.

In some cases experience or subject matter knowledge suggests an appropriate theoretical distribution for a data set. Nelson (1982) discusses some of these cases. The program presented below provides a convenient way to view and compare normal, two-parameter lognormal, three-parameter lognormal, right-tail half-normal, left-tail half-normal, exponential, two-parameter Weibull, and three-parameter Weibull probability plots.

Program Description

When the user requests a particular type of probability plot, two output screens are produced. The first indicates the type of plot requested and lists the vertical and horizontal coordinates of the points to be plotted. The second screen displays the probability plot. The theoretical quantiles are plotted on the vertical axis and the data quantiles are plotted on the horizontal axis. Table 1 shows the values plotted for each type of plot.

Nelson (1982) provides the following motivation for use of the cumulative probability values $p_i = (i - 0.5)/n$. The smallest of the n observations is assumed to represent the first $(1/n)100\%$ of the population from which the data values were drawn. This part of the population covers the cumulative probability values from 0 to $1/n$. The middle of this interval is $(1 - 0.5)/n$, so we plot the quantile corresponding to this cumulative probability value against the smallest data value. In general, the i^{th} smallest observation represents cumulative probability values between $(i - 1)/n$ and i/n. Since the mid-

Ms. Jensen is a Graduate Research Assistant in the Statistics Department and the ISU Industry/University Affiliate Program in Productivity, Quality, and Reliability. She is a Student Member of ASQC.

Dr. Crowder is a Senior Statistical Engineer in the Process Analysis Department. He is a Member of ASQC.

Dr. Vardeman is a Professor in the Statistics and Industrial Engineering Departments. He is a Senior Member of ASQC.

TABLE 1. Values Plotted for Each Type of Plot

Theoretical distribution	Vertical coordinate	Horizontal coordinate
Normal[1]	$\Phi^{-1}\left(\frac{i-0.5}{n}\right)$	i^{th} smallest data value
Two-parameter lognormal[2]	$\Phi^{-1}\left(\frac{i-0.5}{n}\right)$	log(i^{th} smallest data value)
Three-parameter lognormal[3]	$\exp\left[\alpha\Phi^{-1}\left(\frac{i-0.5}{n}\right)\right]$	i^{th} smallest data value
Right-tail half-normal	$\Phi^{-1}\left[0.50+\left(\frac{i-0.5}{n}\right)/2\right]$	i^{th} smallest data value
Left-tail half-normal	$\Phi^{-1}\left[\left(\frac{i-0.5}{n}\right)/2\right]$	i^{th} smallest data value
Exponential	$-\log\left(1-\frac{i-0.5}{n}\right)$	i^{th} smallest data value
Two-parameter Weibull	$\log\left[-\log\left(1-\frac{i-0.5}{n}\right)\right]$	log(i^{th} smallest data value)
Three-parameter Weibull[4]	$\left[-\log\left(1-\frac{i-0.5}{n}\right)\right]^{1/c}$	i^{th} smallest data value

[1] $\Phi^{-1}(p)$ is the standard normal quantile function (the inverse of the standard normal distribution function).

[2] All logarithms used in the computer program and in this paper are natural logarithms (base e).

[3] The lognormal distribution function is $F(y) = \Phi\left[\frac{\log(y-\theta)-\zeta}{\sigma}\right]$ for $y > \theta$, where σ must be specified by the user.

[4] The Weibull distribution function is $F(y) = 1 - \exp\left[-\left(\frac{y-\theta}{\alpha}\right)^c\right]$ for $y > \theta$, where c must be specified by the user.

dle of this interval is $(i - 0.5)/n$, we plot the quantile corresponding to this cumulative probability value against the i^{th} smallest observation.

The normal probability plot is a plot of normal quantiles $\Phi^{-1}\left(\frac{i-0.5}{n}\right)$ versus the ordered data values (the quantiles of the data set). The resulting plot is equivalent to that obtained by plotting $\frac{i-0.5}{n}$ versus the ordered data values on normal probability paper. Since the quantile function for the standard normal distribution cannot be written in closed form, the values of this function for given cumulative probabilities are evaluated using Algorithm AS 111, Beasley and Springer (1977). This algorithm appears in the program code as DOUBLE PRECISION FUNCTION PN. (The function PN is also used in constructing the lognormal and half-normal plots.) The mean μ and standard deviation σ of the normal distribution may be estimated from a straight line drawn through the plotted points. The x-intercept (i.e., the horizontal coordinate of the intersection between the line and the horizontal axis) gives an estimate of μ and the inverse of the slope of the line yields an estimate of σ.

The three-parameter lognormal probability plot is a plot of the quantiles of the log-normal distribution versus the ordered data values. The lognormal distribution function is

$$F(y) = \Phi\left[\frac{\log(y-\theta)-\zeta}{\sigma}\right]$$

for $y > \theta$ (see Johnson and Kotz [1970]). Note that three parameters are involved: a threshold parameter θ, a scale parameter ζ, and a shape parameter $\sigma > 0$. Thus the general quantile function of the lognormal distribution is

$$y_p = \theta + \exp[\sigma\Phi^{-1}(p) + \zeta],$$

where p is a given cumulative probability value. The "standard" lognormal quantile function (with $\theta = 0$, $\zeta = 0$, and user-supplied $\sigma > 0$) is used to construct the plot. Thus the three-parameter lognormal probability plot has vertical coordinates $\exp\left[\sigma\Phi^{-1}\left(\frac{i-0.5}{n}\right)\right]$ and the ordered data values as horizonal coordinates. If the value of the shape parameter σ is unknown, it may be necessary to generate plots for a range of σ values to find a value that yields a linear pattern. Then the x-intercept provides an estimate of θ and the log of the inverse slope provides an estimate of ζ.

In the two-parameter lognormal probability plot it is assumed that the threshold parameter θ is zero (i.e., that the smallest possible value is zero). The data are transformed to a natural log scale and plotted versus standard normal quantiles. The lognormal parameters ζ and σ can be estimated from the x-intercept and the inverse of the slope of the line drawn through the plotted points, respectively.

The theoretical quantiles used in the half-normal probability plots are those from the right and left sides of the standard normal distribution. The $\left(\frac{i-0.5}{n}\right)$ quantile of the right-tail half-normal distribution is the $0.50 + \left(\frac{i-0.5}{2n}\right)$ quantile of the standard normal distribution and the $\left(\frac{i-0.5}{n}\right)$ quantile of the left-tail half-normal distribution is the $\left(\frac{i-0.5}{2n}\right)$ quantile of the standard normal distribution.

The exponential distribution function is

$$F(y) = 1 - \exp\left[-\left(\frac{y-\theta}{\lambda}\right)\right]$$

for $y > \theta$, so the general quantile function of the exponential distribution is

$$y_p = \theta - \lambda \log(1-p)$$

where p is a given cumulative probability value. The "standard" exponential quantile function (with $\theta = 0$ and $\lambda = 1$) is used to construct the plot. Thus, the exponential probability plot has vertical coordinates $\left[-\log\left(1 - \frac{i-0.5}{n}\right)\right]$ and ordered data values as horizontal coordinates. The parameter λ (the mean) can be estimated from the inverse of the slope of a line drawn through the plotted points, and the threshold parameter θ can be estimated from the x-intercept.

The three-parameter Weibull distribution function with shape parameter c, scale parameter α, and location parameter θ is

$$F(y) = 1 - \exp\left[-\left(\frac{y-\theta}{\alpha}\right)^c\right]$$

for $y \geq \theta$ and the general Weibull quantile function is

$$y_p = \alpha[-\log(1-p)]^{1/c} + \theta. \qquad (1)$$

The "standard" Weibull quantile function (with $\theta = 0$, $\alpha = 1$, and user-supplied $c > 0$) is used to construct the three-parameter Weibull probability plot. Thus $\left[-\log\left(1 - \frac{i-0.5}{n}\right)\right]^{1/c}$ is plotted versus the ordered data values. If c is unknown, it may be necessary to construct plots for a series of c values to obtain a linear pattern. The x-intercept can then be used to obtain an estimate of θ, and the inverse of the slope can be used to obtain an estimate of α. Note that $c = 1$ produces an exponential probability plot.

The two-parameter Weibull probability plot is appropriate when the threshold parameter θ is known to be zero. The plot is based on the linear relationship between log-transformed Weibull data values and $\log[-\log(1-p)]$ given by the log-transformation of equation (1) with $\theta = 0$:

$$\log(y_p) = \log(\alpha) + (1/c)[\log[-\log(1-p)]]. \qquad (2)$$

The two-parameter Weibull option plots the values $\log\left[-\log\left(1 - \frac{i-0.5}{n}\right)\right]$ on the vertical axis and ordered log-transformed data values on the horizontal axis. After drawing a line through the plotted points, $\log(\alpha)$ can be estimated from the x-intercept and c can be estimated from the slope of the line. Note that the distribution function of the type I extreme value distribution is

$$F(y) = 1 - \exp\left[-\exp\left(-\frac{y}{\alpha}\right)\right]$$

for $y > 0$. Thus, the quantile function for the type I extreme value distribution is

$$y_p = \alpha \log(-\log(1-p))$$

and we see that the vertical coordinates of the two-parameter Weibull probability plot are the quantiles of the type I extreme value distribution with $\alpha = 1$ (See Nelson [1982] and Johnson and Kotz [1970]).

Program Operation

The program runs in an interactive mode and begins by asking the user for the number of data values, the name of the data variable, and the individual data values. After the user enters all of the data values and presses RETURN, the values entered are displayed. The user may then check the data values and choose whether to edit them.

The data editing routine allows the user to delete, add, or change observations. The user is presented with a menu containing these three options and the "STOP EDITING" option. The program provides the prompting necessary to accomplish each editing option.

When the user chooses to stop editing (or if the user chooses not to edit), the main menu appears. This menu offers choices to edit the data, make one of the eight types of probability plots, or exit from the program. If the user requests a plot, the two output screens are displayed and the user returns to the main menu. If the user chooses to edit the data, the editing routine is run and then the main menu is returned.

The present version of the program allows for data entry only from the keyboard (and not from stored files) and is primarily intended for producing quick plots for relatively small data sets. The program allows up to 100 data values. This limit may be changed by replacing "100" by the desired limit each time it occurs in the program code. It appears several times as the dimension of arrays, once in a warning message to the user and once in an "IF" statement.

The two-parameter lognormal and two-parameter Weibull probability plotting procedures require that all the data values be positive because they will be transformed to a log scale. If there are negative values in the data set, an error message is displayed and the user returns to the main menu.

Examples

Example 1

The data in Table 2 are taken from page 159 of Box, Hunter, and Hunter (1978). They are yields from chemical reactions using two different methods. Each method was used 10 times. The output from two runs of the computer program is given in Output Listings 1a and 1b. Output Listing 1a shows the steps required and output generated in producing a normal probability plot of the method A data. Output Listing 1b shows the same for the method B data and also shows the data editing process.

TABLE 2. Yield Results for a Chemical Reaction

Method A	Method B
54.6	74.9
45.8	78.3
57.4	80.4
40.1	58.7
56.3	68.1
51.5	64.7
50.7	66.5
64.5	73.5
52.6	81.0
48.6	73.7

TABLE 3. Class H Insulation Life Data at 260°C

Hours to failure
600
744
744
744
912
1228
1320
1464
1608
1896

Example 2

The data in Table 3 are taken from page 113 of Nelson (1982). They are hours until failure for specimens of Class H electrical insulation material at 260°C. Output Listing 2 shows two-parameter lognormal, normal, and right-tail half-normal plots for these data. The two-parameter lognormal plot produced by this program can be compared to the plot given on page 114 of Nelson (1982). (Note that the horizontal and vertical axes are reversed from the convention used in this program.) The two-parameter lognormal is a reasonable model to try first for these data because

TABLE 4. Times to Breakdown of an Insulating Fluid at 34 kV

Minutes
0.19
0.78
0.96
1.31
2.78
3.16
4.15
4.67
4.85
6.50
7.35
8.01
8.27
12.06
31.75
32.52
33.91
36.71
72.89

the threshold parameter is known to be zero and this model is often used to describe the life of electrical insulation. With the exception of the three equal failure times, the plot is reasonably linear. The normal and right-tail half-normal plots do not provide any improvement in the linearity of the plot.

Example 3

The data in Table 4 are taken from page 105 of Nelson (1982). They are the times to breakdown of an insulating fluid between electrodes at a voltage of 34 kV. Since theory suggests that such failure times follow an exponential distribution, a plot for this model was produced first. This plot is not linear and suggests the model gives a poor fit. Next, two-parameter Weibull and three-parameter Weibull plots were produced. The two-parameter Weibull probability plot displays more linearity than either the exponential probability plot or the three-parameter Weibull plot with an arbitrarily chosen value of $c = 3$. We can estimate c from the slope of the line in the two-parameter Weibull probability plot. This slope is approximately

$$\frac{1.2913 - (-3.6243)}{4.2890 - (-1.6607)} = \frac{4.9156}{5.9497} = 0.8262.$$

Acknowledgments

The authors wish to thank Robert N. Rodriguez and a referee for suggestions that improved the clarity and usefulness of this program.

References

BEASLEY, J. D. and SPRINGER, S. G. (1977). "The Percentage Points of the Normal Distribution." *Applied Statistics* 26, pp. 118–121.

BOX, G. E. P.; HUNTER, W. G.; and HUNTER, J. S. (1978). *Statistics for Experimenters.* John Wiley & Sons, New York, NY.

CHAMBERS, J. M.; CLEVELAND, W. S.; KLEINER, B.; and TUKEY, P. A. (1983). *Graphical Methods for Data Analysis.* Wadsworth International Group, Belmont, CA.

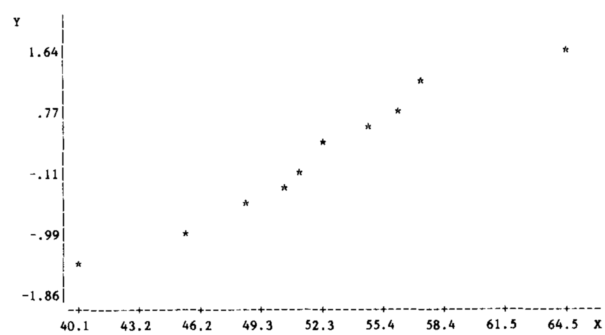
JOHNSON, N. L. and KOTZ, S. (1970). *Continuous Univariate Distributions-1.* John Wiley & Sons, New York, NY.

NELSON, W. (1982). *Applied Life Data Analysis.* John Wiley & Sons, New York, NY.

Key Words: *Exponential Distribution, Half-Normal Distribution, Lognormal Distribution, Normal Distribution, Probability Plotting, Weibull Distribution.*

Output Listing 1a. Output from Example 1a

```
PPLOT

A Probability Plotting Program

ENTER NUMBER OF DATA VALUES:  10

ENTER NAME FOR DATA VARIABLE:  YIELD

ENTER DATA VALUES, LEAVING A BLANK BETWEEN ENTRIES:
54.6 45.8 57.4 40.1 56.3 51.5 50.7 64.5 52.6 48.6

OBSERVATION NUMBER          VALUE

        1                  54.6000
        2                  45.8000
        3                  57.4000
        4                  40.1000
        5                  56.3000
        6                  51.5000
        7                  50.7000
        8                  64.5000
        9                  52.6000
       10                  48.6000

DO YOU WISH TO EDIT THE DATA?  (ENTER Y OR N)  N

OBSERVATION NUMBER          VALUE

        1                  54.6000
        2                  45.8000
        3                  57.4000
        4                  40.1000
        5                  56.3000
        6                  51.5000
        7                  50.7000
        8                  64.5000
        9                  52.6000
       10                  48.6000

STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE

CHOOSE OPTION FOR EDITING OR PLOTTING DATA:

   (1) EDIT DATA
   (2) NORMAL PLOT
   (3) TWO-PARAMETER LOGNORMAL PLOT
   (4) THREE-PARAMETER LOGNORMAL PLOT
   (5) RIGHT-TAIL HALF-NORMAL PLOT
   (6) LEFT-TAIL HALF-NORMAL PLOT
   (7) EXPONENTIAL PLOT
   (8) TWO-PARAMETER WEIBULL PLOT
   (9) THREE-PARAMETER WEIBULL PLOT
  (10) EXIT FROM THE PROGRAM

ENTER NUMBER OF SELECTION:  2

NORMAL PROBABILITY PLOT:                  Y            X

                                     -1.6449      40.1000
                                     -1.0364      45.8000
                                      -.6745      48.6000
                                      -.3853      50.7000
                                      -.1257      51.5000
                                       .1257      52.6000
                                       .3853      54.6000
                                       .6745      56.3000
                                      1.0364      57.4000
                                      1.6449      64.5000

STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE

              PLOT OF Y=NORMAL QUANTILE VS. X=YIELD
```




```
STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE

CHOOSE OPTION FOR EDITING OR PLOTTING DATA:
```

```
    (1) EDIT DATA
    (2) NORMAL PLOT
    (3) TWO-PARAMETER LOGNORMAL PLOT
    (4) THREE-PARAMETER LOGNORMAL PLOT
    (5) RIGHT-TAIL HALF-NORMAL PLOT
    (6) LEFT-TAIL HALF-NORMAL PLOT
    (7) EXPONENTIAL PLOT
    (8) TWO-PARAMETER WEIBULL PLOT
    (9) THREE-PARAMETER WEIBULL PLOT
   (10) EXIT FROM THE PROGRAM


ENTER NUMBER OF SELECTION: 10
Stop - Program terminated.
```

Output Listing 1b. Output from Example 1b

```
                         PPLOT

             A Probability Plotting Program


ENTER NUMBER OF DATA VALUES:  10

ENTER NAME FOR DATA VARIABLE:  YIELD

ENTER DATA VALUES, LEAVING A BLANK BETWEEN ENTRIES:
74.9 78.3 80.4 58.7 66.1 64.7 66.5 73.5 80.1 73.7


OBSERVATION NUMBER            VALUE

         1                    74.9000
         2                    78.3000
         3                    80.4000
         4                    58.7000
         5                    66.1000
         6                    64.7000
         7                    66.5000
         8                    73.5000
         9                    80.1000
        10                    73.7000

DO YOU WISH TO EDIT THE DATA?  (ENTER Y OR N)  Y


SELECT OPTION FOR EDITING DATA:

    (1) DELETE OBSERVATIONS
    (2) ADD OBSERVATIONS
    (3) CHANGE OBSERVATIONS
    (4) STOP EDITING

ENTER NUMBER OF SELECTION:  3


OBSERVATION NUMBER            VALUE

         1                    74.9000
         2                    78.3000
         3                    80.4000
         4                    58.7000
         5                    66.1000
         6                    64.7000
         7                    66.5000
         8                    73.5000
         9                    80.1000
        10                    73.7000


HOW MANY OF THESE OBSERVATIONS DO YOU WISH TO CHANGE?  2

ENTER THE OBSERVATION NUMBERS OF THOSE YOU WISH TO CHANGE.
LEAVE A BLANK BETWEEN ENTRIES.
5 9

ENTER THE NEW DATA VALUES:

OBSERVATION NUMBER 5:  OLD VALUE = 66.1000     NEW VALUE = 68.1
OBSERVATION NUMBER 9:  OLD VALUE = 80.1000     NEW VALUE = 81.0


OBSERVATION NUMBER            VALUE

         1                    74.9000
         2                    78.3000
         3                    80.4000
         4                    58.7000
         5                    68.1000
         6                    64.7000
         7                    66.5000
         8                    73.5000
         9                    81.0000
        10                    73.7000
```

```
SELECT OPTION FOR EDITING DATA:

    (1) DELETE OBSERVATIONS
    (2) ADD OBSERVATIONS
    (3) CHANGE OBSERVATIONS
    (4) STOP EDITING

ENTER NUMBER OF SELECTION:  4

OBSERVATION NUMBER            VALUE

         1                    74.9000
         2                    78.3000
         3                    80.4000
         4                    58.7000
         5                    68.1000
         6                    64.7000
         7                    66.5000
         8                    73.5000
         9                    81.0000
        10                    73.7000

STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE




CHOOSE OPTION FOR EDITING OR PLOTTING DATA:


    (1) EDIT DATA
    (2) NORMAL PLOT
    (3) TWO-PARAMETER LOGNORMAL PLOT
    (4) THREE-PARAMETER LOGNORMAL PLOT
    (5) RIGHT-TAIL HALF-NORMAL PLOT
    (6) LEFT-TAIL HALF-NORMAL PLOT
    (7) EXPONENTIAL PLOT
    (8) TWO-PARAMETER WEIBULL PLOT
    (9) THREE-PARAMETER WEIBULL PLOT
   (10) EXIT FROM THE PROGRAM


ENTER NUMBER OF SELECTION:  2

NORMAL PROBABILITY PLOT:                 Y             X

                                     -1.6449        58.7000
                                     -1.0364        64.7000
                                      -.6745        66.5000
                                      -.3853        68.1000
                                      -.1257        73.5000
                                       .1257        73.7000
                                       .3853        74.9000
                                       .6745        78.3000
                                      1.0364        80.4000
                                      1.6449        81.0000


STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE


                  PLOT OF Y=NORMAL QUANTILE VS. X=YIELD

  Y  |
     |
 1.64|                                                                *
     |
     |                                                              *
     |
  .77|                                                         *
     |                                               *
     |                                            *
     |
 -.11|                                           *
     |                           *
     |                       *
     |
 -.99|                  *
     |
     | *
     |
-1.86|
     -+-------+-------+-------+-------+-------+-------+-------+-------+----
     58.7    61.5    64.3    67.1    69.8    72.6    75.4    78.2    81.0  X
STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE


CHOOSE OPTION FOR EDITING OR PLOTTING DATA:


    (1) EDIT DATA
    (2) NORMAL PLOT
    (3) TWO-PARAMETER LOGNORMAL PLOT
    (4) THREE-PARAMETER LOGNORMAL PLOT
    (5) RIGHT-TAIL HALF-NORMAL PLOT
    (6) LEFT-TAIL HALF-NORMAL PLOT
    (7) EXPONENTIAL PLOT
```

```
    (8) TWO-PARAMETER WEIBULL PLOT
    (9) THREE-PARAMETER WEIBULL PLOT
   (10) EXIT FROM THE PROGRAM


ENTER NUMBER OF SELECTION:  10
Stop - Program terminated.
```

Output Listing 2. Output from Example 2

```
                          PPLOT

              A Probability Plotting Program


ENTER NUMBER OF DATA VALUES:  10

ENTER NAME FOR DATA VARIABLE:  HOURS

ENTER DATA VALUES, LEAVING A BLANK BETWEEN ENTRIES:
600 744 744 744 912 1228 1320 1464 1608 1896

OBSERVATION NUMBER           VALUE

        1                    600.0000
        2                    744.0000
        3                    744.0000
        4                    744.0000
        5                    912.0000
        6                   1228.0000
        7                   1320.0000
        8                   1464.0000
        9                   1608.0000
       10                   1896.0000

DO YOU WISH TO EDIT THE DATA?  (ENTER Y OR N)  N

OBSERVATION NUMBER           VALUE

        1                    600.0000
        2                    744.0000
        3                    744.0000
        4                    744.0000
        5                    912.0000
        6                   1228.0000
        7                   1320.0000
        8                   1464.0000
        9                   1608.0000
       10                   1896.0000

STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE

CHOOSE OPTION FOR EDITING OR PLOTTING DATA:


    (1) EDIT DATA
    (2) NORMAL PLOT
    (3) TWO-PARAMETER LOGNORMAL PLOT
    (4) THREE-PARAMETER LOGNORMAL PLOT
    (5) RIGHT-TAIL HALF-NORMAL PLOT
    (6) LEFT-TAIL HALF-NORMAL PLOT
    (7) EXPONENTIAL PLOT
    (8) TWO-PARAMETER WEIBULL PLOT
    (9) THREE-PARAMETER WEIBULL PLOT
   (10) EXIT FROM THE PROGRAM


ENTER NUMBER OF SELECTION:  3


TWO-PARAMETER LOGNORMAL PROBABILITY PLOT:            Y            X

                                                -1.6449        6.3969
                                                -1.0364        6.6120
                                                 -.6745        6.6120
                                                 -.3853        6.6120
                                                 -.1257        6.8156
                                                  .1257        7.1131
                                                  .3853        7.1854
                                                  .6745        7.2889
                                                 1.0364        7.3827
                                                 1.6449        7.5475


STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE
```

```
                 PLOT OF Y-NORMAL QUANTILE VS. X-LOG HOURS

Y     |
  1.64|                                                                 *
      |
      |                                                       *
      |
   .77|                                                  *
      |                                            *
      |                                        *
      |
  -.11|                        *
      |            *
      |            *
      |
  -.99|            *
      |
      | *
      |
 -1.86|
      -+-------+-------+-------+-------+-------+-------+-------+-------+----
      6.4     6.5     6.7     6.8     7.0     7.1     7.3     7.4     7.5  X

STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE



CHOOSE OPTION FOR EDITING OR PLOTTING DATA:


    (1) EDIT DATA
    (2) NORMAL PLOT
    (3) TWO-PARAMETER LOGNORMAL PLOT
    (4) THREE-PARAMETER LOGNORMAL PLOT
    (5) RIGHT-TAIL HALF-NORMAL PLOT
    (6) LEFT-TAIL HALF-NORMAL PLOT
    (7) EXPONENTIAL PLOT
    (8) TWO-PARAMETER WEIBULL PLOT
    (9) THREE-PARAMETER WEIBULL PLOT
   (10) EXIT FROM THE PROGRAM


ENTER NUMBER OF SELECTION:  2

NORMAL PROBABILITY PLOT:                  Y             X

                                      -1.6449        600.0000
                                      -1.0364        744.0000
                                       -.6745        744.0000
                                       -.3853        744.0000
                                       -.1257        912.0000
                                        .1257       1228.0000
                                        .3853       1320.0000
                                        .6745       1464.0000
                                       1.0364       1608.0000
                                       1.6449       1896.0000


STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE


                 PLOT OF Y-NORMAL QUANTILE VS. X-HOURS

Y     |
  1.64|                                                                 *
      |
      |                                                  *
      |
   .77|                                           *
      |                                    *
      |                                *
      |
  -.11|                *
      |        *
      |        *
      |
  -.99|        *
      |
      | *
      |
 -1.86|
      -+-------+-------+-------+-------+-------+-------+-------+-------+----
    600.0   762.0   924.0  1086.0  1248.0  1410.0  1572.0  1734.0  1896.0  X

STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE

CHOOSE OPTION FOR EDITING OR PLOTTING DATA:


    (1) EDIT DATA
    (2) NORMAL PLOT
    (3) TWO-PARAMETER LOGNORMAL PLOT
    (4) THREE-PARAMETER LOGNORMAL PLOT
    (5) RIGHT-TAIL HALF-NORMAL PLOT
    (6) LEFT-TAIL HALF-NORMAL PLOT
    (7) EXPONENTIAL PLOT
    (8) TWO-PARAMETER WEIBULL PLOT
    (9) THREE-PARAMETER WEIBULL PLOT
   (10) EXIT FROM THE PROGRAM
```

```
ENTER NUMBER OF SELECTION:  5


RIGHT-TAIL HALF-NORMAL PROBABILITY PLOT:          Y            X

                                              .0627      600.0000
                                              .1891      744.0000
                                              .3186      744.0000
                                              .4538      744.0000
                                              .5978      912.0000
                                              .7554     1228.0000
                                              .9346     1320.0000
                                             1.1503     1464.0000
                                             1.4395     1608.0000
                                             1.9600     1896.0000


STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE

              PLOT OF Y=RIGHT-TAIL NORMAL QUANTILE VS. X = HOURS

  Y   |
      |
  1.96|                                                            *
      |
      |
  1.45|                                                 *
      |                                            *
      |
   .95|                                       *
      |                                    *
      |                    *
      |       *
   .44|       *
      |
      |       *
      | *
  -.06|
      -+--------+--------+--------+--------+--------+--------+--------+--------+----
    600.0    762.0    924.0   1086.0   1248.0   1410.0   1572.0   1734.0   1896.0  X
STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE



CHOOSE OPTION FOR EDITING OR PLOTTING DATA:


     (1) EDIT DATA
     (2) NORMAL PLOT
     (3) TWO-PARAMETER LOGNORMAL PLOT
     (4) THREE-PARAMETER LOGNORMAL PLOT
     (5) RIGHT-TAIL HALF-NORMAL PLOT
     (6) LEFT-TAIL HALF-NORMAL PLOT
     (7) EXPONENTIAL PLOT
     (8) TWO-PARAMETER WEIBULL PLOT
     (9) THREE-PARAMETER WEIBULL PLOT
    (10) EXIT FROM THE PROGRAM


ENTER NUMBER OF SELECTION:  10
Stop - Program terminated.
```

Output Listing 3. Output from Example 3

```
                         PPLOT

                 A Probability Plotting Program


ENTER NUMBER OF DATA VALUES:  19

ENTER NAME FOR DATA VARIABLE:  MINUTES

ENTER DATA VALUES, LEAVING A BLANK BETWEEN ENTRIES:
0.19 0.78 0.96 1.31 2.78 3.16 4.15 4.67 4.85 6.50 7.35
8.01 8.27 12.06 31.75 32.52 33.91 36.71 72.89


OBSERVATION NUMBER          VALUE

         1                   .1900
         2                   .7800
         3                   .9600
         4                  1.3100
         5                  2.7800
         6                  3.1600
         7                  4.1500
         8                  4.6700
         9                  4.8500
        10                  6.5000
        11                  7.3500
        12                  8.0100
        13                  8.2700
        14                 12.0600
        15                 31.7500
        16                 32.5200
        17                 33.9100
        18                 36.7100
        19                 72.8900

DO YOU WISH TO EDIT THE DATA?  (ENTER Y OR N)  N

OBSERVATION NUMBER          VALUE

         1                   .1900
         2                   .7800
         3                   .9600
         4                  1.3100
         5                  2.7800
         6                  3.1600
         7                  4.1500
         8                  4.6700
         9                  4.8500
        10                  6.5000
        11                  7.3500
        12                  8.0100
        13                  8.2700
        14                 12.0600
        15                 31.7500
        16                 32.5200
        17                 33.9100
        18                 36.7100
        19                 72.8900

STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE



CHOOSE OPTION FOR EDITING OR PLOTTING DATA:


     (1) EDIT DATA
     (2) NORMAL PLOT
     (3) TWO-PARAMETER LOGNORMAL PLOT
     (4) THREE-PARAMETER LOGNORMAL PLOT
     (5) RIGHT-TAIL HALF-NORMAL PLOT
     (6) LEFT-TAIL HALF-NORMAL PLOT
     (7) EXPONENTIAL PLOT
     (8) TWO-PARAMETER WEIBULL PLOT
     (9) THREE-PARAMETER WEIBULL PLOT
    (10) EXIT FROM THE PROGRAM


ENTER NUMBER OF SELECTION:  7

EXPONENTIAL PROBABILITY PLOT:                  Y            X

                                             .0267        .1900
                                             .0822        .7800
                                             .1411        .9600
                                             .2036       1.3100
                                             .2703       2.7800
                                             .3417       3.1600
                                             .4187       4.1500
                                             .5021       4.6700
                                             .5931       4.8500
                                             .6931       6.5000
                                             .8044       7.3500
                                             .9295       8.0100
                                            1.0726       8.2700
                                            1.2397      12.0600
                                            1.4404      31.7500
                                            1.6917      32.5200
                                            2.0281      33.9100
                                            2.5390      36.7100
                                            3.6376      72.8900


STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE

                   PLOT OF Y=EXPONENTIAL QUANTILE VS. X=MINUTES
  Y   |
      |
  3.64|                                                                     *
      |
      |
      |
  2.67|                                  *
      |
      |                               *
      |
  1.71|                              *
      |         *                   *
      |        *
      |       *
   .75|     **
      |   **
      | *
      |
  -.21|
      -+--------+--------+--------+--------+--------+--------+--------+--------+----
      .2      9.3     18.4     27.5     36.5     45.6     54.7     63.8     72.9  X

STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE
```

```
CHOOSE OPTION FOR EDITING OR PLOTTING DATA:



     (1) EDIT DATA
     (2) NORMAL PLOT
     (3) TWO-PARAMETER LOGNORMAL PLOT
     (4) THREE-PARAMETER LOGNORMAL PLOT
     (5) RIGHT-TAIL HALF-NORMAL PLOT
     (6) LEFT-TAIL HALF-NORMAL PLOT
     (7) EXPONENTIAL PLOT
     (8) TWO-PARAMETER WEIBULL PLOT
     (9) THREE-PARAMETER WEIBULL PLOT
    (10) EXIT FROM THE PROGRAM


ENTER NUMBER OF SELECTION:  8
```

TWO-PARAMETER WEIBULL PROBABILITY PLOT:

Y	X
-3.6243	-1.6607
-2.4981	-.2485
-1.9584	-.0408
-1.5916	.2700
-1.3083	1.0225
-1.0737	1.1506
-.8706	1.4231
-.6890	1.5412
-.5225	1.5790
-.3665	1.8718
-.2177	1.9947
-.0731	2.0807
.0701	2.1126
.2149	2.4899
.3649	3.4579
.5257	3.4819
.7071	3.5237
.9318	3.6030
1.2913	4.2890

```
STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE

        PLOT OF Y - TYPE I EXTREME VALUE QUANTILE VS. X - LOG MINUTES

   Y  |
      |
  1.29|                                                                 *
      |                                                       **
      |                                                        *
      |                                         *   *
  -.02|                                        **
      |                                   *  *
      |                                  **
      |                             * *
 -1.33|                     *
      |                  *
      |
      |                *
 -2.64|
      |
      | *
      |
 -3.95|
     -+-------+-------+-------+-------+-------+-------+-------+-------+----
    -1.7     -.9     -.2      .6     1.3     2.1     2.8     3.5     4.3  X
STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE



CHOOSE OPTION FOR EDITING OR PLOTTING DATA:



     (1) EDIT DATA
     (2) NORMAL PLOT
     (3) TWO-PARAMETER LOGNORMAL PLOT
     (4) THREE-PARAMETER LOGNORMAL PLOT
     (5) RIGHT-TAIL HALF-NORMAL PLOT
     (6) LEFT-TAIL HALF-NORMAL PLOT
     (7) EXPONENTIAL PLOT
     (8) TWO-PARAMETER WEIBULL PLOT
     (9) THREE-PARAMETER WEIBULL PLOT
    (10) EXIT FROM THE PROGRAM


ENTER NUMBER OF SELECTION:  9

 ENTER THE VALUE OF THE SHAPE PARAMETER (C)
 FOR THE WEIBULL DISTRIBUTION:  3
```

THREE-PARAMETER WEIBULL PROBABILITY PLOT:

Y	X
.2988	.1900
.4349	.7800
.5206	.9600
.5883	1.3100
.6466	2.7800
.6991	3.1600
.7481	4.1500
.7948	4.6700
.8402	4.8500
.8850	6.5000
.9300	7.3500
.9759	8.0100
1.0236	8.2700
1.0742	12.0600
1.1293	31.7500
1.1915	32.5200
1.2658	33.9100
1.3642	36.7100
1.5379	72.8900

```
STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE

            PLOT OF Y-WEIBULL QUANTILE VS. X-MINUTES      ** C =   3.00 **

   Y  |
      |
  1.54|                                                                *
      |
      |                                  *
      |                               *
  1.21|                             **
      |            *
      |        **
      |       **
   .88|     **
      |     *
      |    *
      |  *
   .55|  *
      |  *
      |  *
      |
   .22|
     -+-------+-------+-------+-------+-------+-------+-------+-------+----
      .2     9.3    18.4    27.5    36.5    45.6    54.7    63.8    72.9  X
STRIKE CARRIAGE RETURN WHEN YOU WISH TO CONTINUE



CHOOSE OPTION FOR EDITING OR PLOTTING DATA:



     (1) EDIT DATA
     (2) NORMAL PLOT
     (3) TWO-PARAMETER LOGNORMAL PLOT
     (4) THREE-PARAMETER LOGNORMAL PLOT
     (5) RIGHT-TAIL HALF-NORMAL PLOT
     (6) LEFT-TAIL HALF-NORMAL PLOT
     (7) EXPONENTIAL PLOT
     (8) TWO-PARAMETER WEIBULL PLOT
     (9) THREE-PARAMETER WEIBULL PLOT
    (10) EXIT FROM THE PROGRAM


ENTER NUMBER OF SELECTION:  10
Stop - Program terminated.
```

Program Listing

```
      REAL*8 DATA(100),SDATA(100)
      INTEGER N,SEL
      CHARACTER*8 XLABEL
C
      CALL INPUT(N,DATA,SDATA,XLABEL)
C
  101 WRITE(*,103)
  103 FORMAT(8(/),1X,'CHOOSE OPTION FOR EDITING OR ',
     +'PLOTTING DATA:  ',
     +////,5X,' (1) EDIT DATA',
     +/,5X,' (2) NORMAL PLOT ',
     +/,5X,' (3) TWO-PARAMETER LOGNORMAL PLOT ',
     +/,5X,' (4) THREE-PARAMETER LOGNORMAL PLOT',
     +/,5X,' (5) RIGHT-TAIL HALF-NORMAL PLOT ',
     +/,5X,' (6) LEFT-TAIL HALF-NORMAL PLOT ',
     +/,5X,' (7) EXPONENTIAL PLOT ',
     +/,5X,' (8) TWO-PARAMETER WEIBULL PLOT ',
     +/,5X,' (9) THREE-PARAMETER WEIBULL PLOT ',
     +/,5X,'(10) EXIT FROM THE PROGRAM',
     +////,1X,'ENTER NUMBER OF SELECTION:  ',\)
C
      READ(*,*) SEL
      IF (SEL.GE.1.AND.SEL.LE.10) GOTO 107
C
      WRITE(*,105)
```

```
  105 FORMAT(//,1X,'INVALID SELECTION.  PLEASE TRY ',
     +'AGAIN')
      GOTO 101
C
  107 GOTO (110,120,130,140,150,160,170,180,190,200),
     +        SEL
C
  110 CALL EDIT(N,DATA,SDATA)
      GOTO 101
C
  120 CALL NPLOT(N,SDATA,XLABEL)
      GOTO 101
C
  130 CALL LN2PLT(N,SDATA,XLABEL)
      GOTO 101
C
  140 CALL LN3PLT(N,SDATA,XLABEL)

      GOTO 101
C
  150 CALL HRPLOT(N,SDATA,XLABEL)
      GOTO 101
C
  160 CALL HLPLOT(N,SDATA,XLABEL)
      GOTO 101
C
  170 CALL EPLOT(N,SDATA,XLABEL)
      GOTO 101
C
  180 CALL W2PLOT(N,SDATA,XLABEL)
      GOTO 101
C
  190 CALL W3PLOT(N,SDATA,XLABEL)
      GOTO 101
C
  200 STOP
      END
C
C
C---------------------------------------------------
C
      SUBROUTINE INPUT(N,DATA,SDATA,XLABEL)
C
      INTEGER N
      REAL*8 DATA(100),SDATA(100)
      CHARACTER*8 XLABEL
      CHARACTER*1 ED
C
      WRITE(*,200)
  200 FORMAT(////,32X,'PPLOT',
     +///,20X,'A Probability Plotting Program')
C
  300 WRITE(*,305)
  305 FORMAT(////,' ENTER NUMBER OF DATA VALUES:  ',\)
      READ(*,*) N
      IF (N.GE.1.AND.N.LE.100) GOTO 315
C
      WRITE(*,310)
  310 FORMAT(//,1X,'THE NUMBER OF DATA VALUES MUST ',
     +'BE BETWEEN 1 AND 100.',
     +/,1X,'PLEASE TRY AGAIN.')
      GOTO 300
C
  315 WRITE(*,320)
  320 FORMAT(//,' ENTER NAME FOR DATA VARIABLE:  ',\)
      READ(*,325) XLABEL
  325 FORMAT(A8)
C
      WRITE(*,330)
  330 FORMAT(//,1X,'ENTER DATA VALUES, ',
     +'LEAVING A BLANK BETWEEN ENTRIES:')
      READ(*,*) (DATA(I),I=1,N)

C
      CALL PRDATA(N,DATA)
C
  334 WRITE(*,335)
  335 FORMAT(/,1X,'DO YOU WISH TO EDIT THE DATA?  ',
     +'(ENTER Y OR N)  ',\)
C
      READ(*,340) ED
  340 FORMAT(A1)
      IF (ED.EQ.'N'.OR.ED.EQ.'n'
     +    .OR.ED.EQ.'Y'.OR.ED.EQ.'y') GOTO 345
C
      WRITE(*,341)
  341 FORMAT(//,1X,'INVALID RESPONSE.  ',
     +'PLEASE TRY AGAIN')
      GOTO 334
C
  345 IF (ED.EQ.'N'.OR.ED.EQ.'n') GOTO 350
      CALL EDIT(N,DATA,SDATA)
C
  350 CALL PRDATA(N,DATA)
      CALL SORT(N,DATA,SDATA)
      CALL PAUSE
C
      RETURN
      END
C
C
C---------------------------------------------------
C
      SUBROUTINE PRDATA(N,DATA)
C
      INTEGER N
      REAL*8 DATA(100)
C
      WRITE(*,400)
  400 FORMAT(////,' OBSERVATION NUMBER',10X,'VALUE',/)
C
      DO 410 I=1,N
        WRITE(*,405) I,DATA(I)
  405   FORMAT(8X,I3,15X,F10.4)
  410 CONTINUE
C
      RETURN
      END
C
C
C---------------------------------------------------
C
      SUBROUTINE EDIT(N,DATA,SDATA)
C
      INTEGER N,CH1
      REAL*8 DATA(100),SDATA(100)
C
  500 WRITE(*,505)
  505 FORMAT(////,' SELECT OPTION FOR EDITING DATA:',
     +//,5X,'(1) DELETE OBSERVATIONS',
     +/,5X,'(2) ADD OBSERVATIONS',
     +/,5X,'(3) CHANGE OBSERVATIONS',
     +/,5X,'(4) STOP EDITING',
     +//,1X,'ENTER NUMBER OF SELECTION:  ',\)
      READ(*,*) CH1
      IF (CH1.GE.1.AND.CH1.LE.4) GOTO 515
      WRITE(*,510)
  510 FORMAT(/,'INVALID RESPONSE.  PLEASE TRY AGAIN')
      GOTO 500
C
  515 GOTO (520,525,530,540),CH1
C
  520 CALL DELETE(N,DATA)
      GOTO 500
C
  525 CALL ADD(N,DATA)
      GOTO 500
C
  530 CALL CHANGE(N,DATA)
      GOTO 500
C
  540 CALL SORT(N,DATA,SDATA)
      RETURN
      END
```

```
C
C
C-----------------------------------------------------
C
      SUBROUTINE DELETE(N,DATA)
C
      INTEGER N,NUM,FLAG,INDEX(100),SINDEX(100)
      REAL*8 DATA(100)
C
      CALL PRDATA(N,DATA)
  600 WRITE(*,605)
  605 FORMAT(//,1X,'HOW MANY OF THESE OBSERVATIONS ',
     +'DO YOU WISH TO DELETE?  '\)
      READ(*,*) NUM
      IF (NUM.GE.1.AND.NUM.LE.N) GOTO 615
C
      WRITE(*,610)
  610 FORMAT(//,1X,'INVALID RESPONSE.  ',
     +'PLEASE TRY AGAIN')
      GOTO 600
C
  615 WRITE(*,620)
  620 FORMAT(//,1X,'ENTER THE OBSERVATION NUMBERS ',
     +'OF THOSE YOU WISH TO DELETE.',
     +/,1X,'LEAVE A BLANK BETWEEN ENTRIES.')
      READ(*,*) (INDEX(I),I=1,NUM)
      CALL CHECK(N,NUM,INDEX,FLAG)
      IF (FLAG.EQ.0) GOTO 630
C
      WRITE(*,625) N
  625 FORMAT(/,1X,'THESE NUMBERS MUST BE BETWEEN ',
     +'1 AND ',I3,'.',/,1X,'PLEASE TRY AGAIN.')
      GOTO 615
C
  630 CALL ISORT(NUM,INDEX,SINDEX)
      DO 640 I=1,NUM
        DO 635 J=SINDEX(I),N-1
          DATA(J-I+1)=DATA(J-I+2)
  635   CONTINUE
  640 CONTINUE
C
      N=N-NUM
C
      CALL PRDATA(N,DATA)
      RETURN
      END
C
C-----------------------------------------------------
C
      SUBROUTINE ADD(N,DATA)
C
      INTEGER N,NMORE
      REAL*8 DATA(100)
C
      CALL PRDATA(N,DATA)
  650 WRITE(*,655)
  655 FORMAT(//,1X,'HOW MANY OBSERVATIONS ',
     +'DO YOU WISH TO ADD?  '\)
      READ(*,*) NMORE
      IF ((NMORE+N).LE.100.AND.NMORE.GE.1) GOTO 665
C
      WRITE(*,660)
  660 FORMAT(//,1X,'INVALID RESPONSE.  ',
     +'PLEASE TRY AGAIN')
      GOTO 650
C
  665 WRITE(*,670) NMORE
  670 FORMAT(//,1X,'ENTER THE ',I2,' NEW DATA '
     +'VALUES, LEAVING A BLANK BETWEEN ENTRIES:')
      READ(*,*) (DATA(I),I=N+1,N+NMORE)
C
      N=N+NMORE
C
      CALL PRDATA(N,DATA)
      RETURN
      END
C
C
C-----------------------------------------------------
C
      SUBROUTINE CHANGE(N,DATA)
C
      INTEGER N,NUM,FLAG,INDEX(100),SINDEX(100)
      REAL*8 DATA(100)
C
      CALL PRDATA(N,DATA)
  700 WRITE(*,705)
  705 FORMAT(//,1X,'HOW MANY OF THESE OBSERVATIONS ',
     +'DO YOU WISH TO CHANGE?  '\)
      READ(*,*) NUM
      IF (NUM.GE.1.AND.NUM.LE.N) GOTO 715
C
      WRITE(*,710)
  710 FORMAT(//,1X,'INVALID RESPONSE.  ',
     +'PLEASE TRY AGAIN')
      GOTO 700
C
  715 WRITE(*,720)
  720 FORMAT(//,1X,'ENTER THE OBSERVATION NUMBERS ',
     +'OF THOSE YOU WISH TO CHANGE.',
     +/,1X,'LEAVE A BLANK BETWEEN ENTRIES.')
      READ(*,*) (INDEX(I),I=1,NUM)
      CALL CHECK(N,NUM,INDEX,FLAG)
      IF (FLAG.EQ.0) GOTO 730
C
      WRITE(*,725) N
  725 FORMAT(/,1X,'THESE NUMBERS MUST BE BETWEEN ',
     +'1 AND ',I3,'.',/,1X,'PLEASE TRY AGAIN.')
      GOTO 715
C
  730 CALL ISORT(NUM,INDEX,SINDEX)
      WRITE(*,735)
  735 FORMAT(/,1X,'ENTER THE NEW DATA VALUES:',/)
      DO 745 I=1,NUM
        WRITE(*,740) SINDEX(I),DATA(SINDEX(I))
  740   FORMAT(1X,'OBSERVATION NUMBER ',I3,
     +':  OLD VALUE = ',F10.4,4X,'NEW VALUE = ',\)
        READ(*,*) DATA(SINDEX(I))
  745 CONTINUE
C
      CALL PRDATA(N,DATA)
      RETURN
      END
C
C
C-----------------------------------------------------
C
      SUBROUTINE CHECK(N,NUM,INDEX,FLAG)
C
      INTEGER N,NUM,INDEX(100),FLAG
C
      FLAG=0
      DO 810 I=1,NUM
        IF (INDEX(I).GE.1.AND.INDEX(I).LE.N) GOTO 810
        FLAG=1
  810 CONTINUE
C
      RETURN
      END
C
C
C-----------------------------------------------------
C
      SUBROUTINE PAUSE
C
      CHARACTER*1 GO
C
C  Pause to let user view the display
C
      WRITE(*,70)
   70 FORMAT(/,1X,'STRIKE CARRIAGE RETURN WHEN YOU ',
     +'WISH TO CONTINUE',\)
```

```
      READ(*,75) GO
   75 FORMAT(A1)
C
      CALL WRLINE(2)
      RETURN
      END
C
C
C----------------------------------------------------
C
      SUBROUTINE NPLOT(N,SDATA,XLABEL)
C
      INTEGER N
      REAL*8 SDATA(100),ARG,PN,Y(100)
      CHARACTER*8 XLABEL
C
      WRITE(*,900)
  900 FORMAT(////,1X,'NORMAL PROBABILITY PLOT:',17X,
     +'Y',14X,'X',/)
C
      DO 910 I=1,N
        ARG=(DBLE(I)-.50D0)/DBLE(N)
        Y(I)=PN(ARG)
        WRITE(*,905) Y(I),SDATA(I)
  905   FORMAT(35X,F10.4,5X,F10.4)
  910 CONTINUE
      CALL WRLINE(3)
      CALL PAUSE
C
      WRITE(*,920) XLABEL
  920 FORMAT(//,20X,'PLOT OF Y=NORMAL QUANTILE VS. ',
     +'X=',A8)
      CALL PLTTR(N,SDATA,Y)
C
      RETURN
      END
C
C
C----------------------------------------------------
C
      SUBROUTINE LN2PLT(N,SDATA,XLABEL)
C
      INTEGER N
      REAL*8 SDATA(100),Y(100),LDATA(100),ARG,PN
      CHARACTER*8 XLABEL
C
      IF (SDATA(1).GT.0) GOTO 2005
      WRITE(*,2000)
 2000 FORMAT(//,1X,'A TWO-PARAMETER LOGNORMAL PLOT ',
     +'IS NOT POSSIBLE',/
     +,1X,'BECAUSE OF NEGATIVE DATA VALUES.',//
     +,1X,'PLEASE CHOOSE A DIFFERENT TYPE OF PLOT.')
      CALL WRLINE(4)
      CALL PAUSE
      GOTO 2090
C
 2005 WRITE(*,2007)
 2007 FORMAT(////,1X,'TWO-PARAMETER LOGNORMAL ',
     +'PROBABILITY PLOT:',
     +13X,'Y',14X,'X',/)
C
      DO 2010 I=1,N
        ARG=(DBLE(I)-.50D0)/DBLE(N)
        Y(I)=PN(ARG)
        LDATA(I)=DLOG(SDATA(I))
        WRITE(*,2008) Y(I),LDATA(I)
 2008   FORMAT(48X,F10.4,5X,F10.4)
 2010 CONTINUE
      CALL WRLINE(3)
      CALL PAUSE
C
      WRITE(*,2020) XLABEL
 2020 FORMAT(//,20X,'PLOT OF Y=NORMAL QUANTILE VS. ',
     +'X=LOG ',A8)
      CALL PLTTR(N,LDATA,Y)
C
 2090 RETURN
      END
C
C
C----------------------------------------------------
C
      SUBROUTINE LN3PLT(N,SDATA,XLABEL)
C
      INTEGER N
      REAL*8 SDATA(100),Y(100),ARG,PN,SHAPE
      CHARACTER*8 XLABEL
C
      WRITE(*,2100)
 2100 FORMAT(//,1X,'ENTER THE VALUE OF THE SHAPE '
     +'PARAMETER (SIGMA)',
     +/,1X,'FOR THE LOGNORMAL DISTRIBUTION:   '\)
      READ(*,*) SHAPE
C
 2105 WRITE(*,2107)
 2107 FORMAT(////,1X,'THREE-PARAMETER LOGNORMAL ',
     +'PROBABILITY PLOT:',
     +13X,'Y',14X,'X',/)
C
      DO 2110 I=1,N
        ARG=(DBLE(I)-.50D0)/DBLE(N)
        Y(I)=DEXP(SHAPE*PN(ARG))
        WRITE(*,2108) Y(I),SDATA(I)
 2108   FORMAT(50X,F10.4,5X,F10.4)
 2110 CONTINUE
      CALL WRLINE(3)
      CALL PAUSE
C
      WRITE(*,2120) XLABEL,SHAPE
 2120 FORMAT(//,11X,'PLOT OF Y=LOGNORMAL QUANTILE VS.',
     +' X=',A8,5X,'** SIGMA = ',F6.2,' **')
      CALL PLTTR(N,SDATA,Y)
C
 2190 RETURN
      END
C
C
C----------------------------------------------------
C
      SUBROUTINE HRPLOT(N,SDATA,XLABEL)
C
      INTEGER N
      REAL*8 SDATA(100),Y(100),ARG,PN
      CHARACTER*8 XLABEL
C
      WRITE(*,1105)
 1105 FORMAT(////,1X,'RIGHT-TAIL HALF-NORMAL ',
     +'PROBABILITY PLOT:',12X,'Y',14X,'X',/)
C
      DO 1115 I=1,N
        ARG=(DBLE(I)-.50D0)/DBLE(N)
        Y(I)=PN((ARG/2.0D0)+.50D0)
        WRITE(*,1110) Y(I),SDATA(I)
 1110   FORMAT(46X,F10.4,5X,F10.4)
 1115 CONTINUE
      CALL WRLINE(3)
      CALL PAUSE
C
      WRITE(*,1120) XLABEL
 1120 FORMAT(//,15X,'PLOT OF Y=RIGHT-TAIL NORMAL ',
     +'QUANTILE VS. X = ',A8)
      CALL PLTTR(N,SDATA,Y)
C
      RETURN
      END
C
C
C----------------------------------------------------
C
      SUBROUTINE HLPLOT(N,SDATA,XLABEL)
C
      INTEGER N
```

```
      REAL*8 SDATA(100),Y(100),ARG,PN
      CHARACTER*8 XLABEL
C
      WRITE(*,1205)
 1205 FORMAT(////,1X,'LEFT-TAIL HALF-NORMAL ',
     +'PROBABILITY PLOT:',12X,'Y',14X,'X',/)
C
      DO 1215 I=1,N
        ARG=(DBLE(I)-.50D0)/DBLE(N)
        Y(I)=PN(ARG/2.0D0)
        WRITE(*,1210) Y(I),SDATA(I)
 1210   FORMAT(45X,F10.4,5X,F10.4)
 1215 CONTINUE
      CALL WRLINE(3)
      CALL PAUSE
C
      WRITE(*,1220) XLABEL
 1220 FORMAT(//,15X,'PLOT OF Y=LEFT-TAIL NORMAL ',
     +'QUANTILE VS. X = ',A8)
      CALL PLTTR(N,SDATA,Y)
C
      RETURN
      END
C
C
C-----------------------------------------------------
C
      SUBROUTINE EPLOT(N,SDATA,XLABEL)
C
      INTEGER N
      REAL*8 SDATA(100),ARG,Y(100)
      CHARACTER*8 XLABEL
C
      WRITE(*,1300)
 1300 FORMAT(////,1X,'EXPONENTIAL PROBABILITY PLOT:',
     +17X,'Y',14X,'X',/)
C
      DO 1310 I=1,N
        ARG=(DBLE(I)-.50D0)/DBLE(N)
        Y(I)=-DLOG(1.0D0-ARG)
        WRITE(*,1305) Y(I),SDATA(I)
 1305   FORMAT(40X,F10.4,5X,F10.4)
 1310 CONTINUE
      CALL WRLINE(3)
      CALL PAUSE
C
      WRITE(*,1320) XLABEL
 1320 FORMAT(//,20X,'PLOT OF Y=EXPONENTIAL ',
     +'QUANTILE VS. X=',A8)
      CALL PLTTR(N,SDATA,Y)
C
      RETURN
      END
C
C
C-----------------------------------------------------
C
      SUBROUTINE W2PLOT(N,SDATA,XLABEL)
C
      INTEGER N
      REAL*8 SDATA(100),LDATA(100),ARG,Y(100)
      CHARACTER*8 XLABEL
C
      IF (SDATA(1).GT.0) GOTO 1402
      WRITE(*,1400)
 1400 FORMAT(//,1X,'A TWO-PARAMETER WEIBULL PLOT ',
     +'IS NOT POSSIBLE',/
     +,1X,'BECAUSE OF NEGATIVE DATA VALUES.',//
     +,1X,'PLEASE CHOOSE A DIFFERENT TYPE OF PLOT.')
      CALL WRLINE(4)
      CALL PAUSE
      GOTO 1490
C
 1402 WRITE(*,1403)
 1403 FORMAT(////,1X,'TWO-PARAMETER WEIBULL ',
     +'PROBABILITY PLOT:',
     +12X,'Y',14X,'X',/)
C
      DO 1410 I=1,N
        ARG=(DBLE(I)-.50D0)/DBLE(N)
        Y(I)=DLOG(-DLOG(1.0D0-ARG))
        LDATA(I)=DLOG(SDATA(I))
        WRITE(*,1405) Y(I),LDATA(I)
 1405   FORMAT(45X,F10.4,5X,F10.4)
 1410 CONTINUE
      CALL WRLINE(3)
      CALL PAUSE
C
      WRITE(*,1420) XLABEL
 1420 FORMAT(//,13X,'PLOT OF Y = TYPE I EXTREME ',
     +'VALUE QUANTILE VS. X = LOG ',A8)
      CALL PLTTR(N,LDATA,Y)
C
 1490 RETURN
      END
C
C
C-----------------------------------------------------
C
      SUBROUTINE W3PLOT(N,SDATA,XLABEL)
C
      INTEGER N
      REAL*8 SDATA(100),C,Y(100),ARG
      CHARACTER*8 XLABEL
C
      WRITE(*,1500)
 1500 FORMAT(//,1X,'ENTER THE VALUE OF THE SHAPE '
     +'PARAMETER (C)',
     +/,1X,'FOR THE WEIBULL DISTRIBUTION:   '\)
      READ(*,*) C
C
      WRITE(*,1501)
 1501 FORMAT(////,1X,'THREE-PARAMETER WEIBULL ',
     +'PROBABILITY PLOT:',
     +12X,'Y',14X,'X',/)
C
      DO 1510 I=1,N
        ARG=(DBLE(I)-.50D0)/DBLE(N)
        Y(I)=(-DLOG(1.0D0-ARG))**(1/C)
        WRITE(*,1505) Y(I),SDATA(I)
 1505   FORMAT(47X,F10.4,5X,F10.4)
 1510 CONTINUE
      CALL WRLINE(3)
      CALL PAUSE
C
      WRITE(*,1520) XLABEL,C
 1520 FORMAT(//,13X,'PLOT OF Y=WEIBULL QUANTILE ',
     +'VS. X=',A8,5X,'** C = ',F6.2,' **')
      CALL PLTTR(N,SDATA,Y)
C
      RETURN
      END
C
C
C-----------------------------------------------------
C
      SUBROUTINE SORT(N,OBS,SOBS)
C
C  Sort double precision numbers into ascending order
C
C  Source:  Loeser, Communications of the ACM,
C           Vol. 17, No. 3, page 143.
C
      REAL*8 OBS(N),SOBS(N),S
C
      DO 190 J=1,N
        SOBS(J)=OBS(J)
  190 CONTINUE
C
      I=1
  101 IF (I-N) 102,102,103
  102 I=I+I
      GO TO 101
  103 M=I-1
```

```
  104 M=M/2
      IF (M) 110,110,105
  105 K=N-M
      DO 109 J=1,K
        I=J+M
  106   I=I-M
        IF (I) 109,109,107
  107   L=I+M
        IF (SOBS(L)-SOBS(I)) 108,108,109
  108   S=SOBS(I)
        SOBS(I)=SOBS(L)
        SOBS(L)=S
        GO TO 106
  109 CONTINUE
      GO TO 104
  110 RETURN
      END
C
C-----------------------------------------------------
C
      SUBROUTINE ISORT(N,OBS,SOBS)
C
C  Sort integers into ascending order
C
C  Source:  Loeser, Communications of the ACM,
C           Vol. 17, No. 3, page 143.
C
      INTEGER OBS(N),SOBS(N),S
C
      DO 190 J=1,N
        SOBS(J)=OBS(J)
  190 CONTINUE
C
      I=1
  101 IF (I-N) 102,102,103
  102 I=I+I
      GO TO 101
  103 M=I-1
  104 M=M/2
      IF (M) 110,110,105
  105 K=N-M
      DO 109 J=1,K
        I=J+M
  106   I=I-M
        IF (I) 109,109,107
  107   L=I+M
        IF (SOBS(L)-SOBS(I)) 108,108,109
  108   S=SOBS(I)
        SOBS(I)=SOBS(L)
        SOBS(L)=S
        GO TO 106
  109 CONTINUE
      GO TO 104
  110 RETURN
      END
C
C-----------------------------------------------------
C
      DOUBLE PRECISION FUNCTION PN(P)
C
C   Algorithm AS 111, Applied Statistics (1977),
C   Vol. 26, pp 118-121.
C
      REAL*8 A0,A1,A2,A3,B1,B2,B3,B4,C0,C1,C2,C3,D1,
     +D2,P,Q,R
      A0=2.50662823884D0
      A1=-18.61500062529D0
      A2=41.39119773534D0
      A3=-25.44106049637D0
      B1=-8.47351093090D0
      B2=23.08336743743D0
      B3=-21.06224101826D0
      B4=3.13082909833D0
      C0=-2.78718931138D0
      C1=-2.29796479138D0
      C2=4.85014127135D0
      C3=2.32121276858D0
      D1=3.54388924762D0
      D2=1.63706781897D0
      Q=P-.50D0
      IF (DABS(Q) .GT. .42D0) GO TO 102
      R=Q*Q
      PN=Q*(((A3*R + A2)*R + A1)*R + A0)/
     +((((B4*R + B3)*R + B2)*R + B1)*R + 1.0D0)
      RETURN
C
  102 R=P
      IF (Q .GT. 0.0D0) R=1.0D0-P
      R=DSQRT(-DLOG(R))
      PN=(((C3*R + C2)*R +C1)*R + C0)/
     +((D2*R + D1)*R + 1.0D0)
      IF (Q .LT. 0.0D0) PN=-PN
      RETURN
C
      END
C
C
C-----------------------------------------------------
C
      SUBROUTINE PLTTR(N,HORIZ,VERT)
C
      INTEGER I,J,K,COUNT,PRNTFLG(75)
      REAL*8 VERT(128),HORIZ(128),UP,LO,MX,MN,X(128),
     +DX,DY,XMIN,XMAX
      CHARACTER*1 PRNTLN(68),PRNTCHR(6),GO
      DATA PRNTCHR/' ','*','*','*','*','*'/
C
C  Find largest and smallest horizontal coordinates
C  and determine the horizontal scaling factor, DX.
C
      MN=9999999999.9D0
      MX=-9999999999.9D0
      DO 900 I=1,N
       IF (HORIZ(I) .GT. MX) MX=HORIZ(I)
       IF (HORIZ(I) .LT. MN) MN=HORIZ(I)
  900 CONTINUE
      IF (MX.NE.MN) GOTO 902
      MX=MX+1.0D0
      MN=MN-1.0D0
  902 XMIN=MN
      XMAX=MX
      DX=(MX-MN)/64.0D0
C
C  Do the same for the vertical scale.
C
      MN=9999999999.9D0
      MX=-9999999999.9D0
      DO 905 I=1,N
       IF (VERT(I) .GT. MX) MX=VERT(I)
       IF (VERT(I) .LT. MN) MN=VERT(I)
  905 CONTINUE
      IF (MW.NE.MN) GOTO 908
      MX=MX+1.0D0
      MN=MN-1.0D0
  908 DY=(MX-MN)/15.0D0
C
C  Draw the plot a line at a time.
C
      WRITE (*,910)
  910 FORMAT(/,'    Y',5X,'|',/,9X,'|')
      LO=MX
      COUNT=3
C
      DO 940 I=1,17
        DO 915 J=1,65
          RNTFLG(J)=1
  915   CONTINUE
        UP=LO
        LO=UP-DY
        DO 917 K=1,N
          IF ((VERT(K) .GT. LO) .AND.
     +        (VERT(K) .LE. UP)) THEN
```

```
          J=INT(SNGL((HORIZ(K)-XMIN)/DX))+1
          PRNTFLG(J)=PRNTFLG(J)+1
          IF (PRNTFLG(J) .GT. 6) PRNTFLG(J)=6
        END IF
 917    CONTINUE
      IF (COUNT.EQ.3) THEN
        WRITE (*,920) UP,
     +                 (PRNTCHR(PRNTFLG(J)),J=1,65)
 920    FORMAT (1X,F8.2,'| ',65A1)
        COUNT=0
      ELSE
        WRITE (*,925) (PRNTCHR(PRNTFLG(J)),J=1,65)
 925    FORMAT (9X,'| ',65A1)
        COUNT=COUNT+1
      ENDIF
 940 CONTINUE
C
C  Put the labels under the horizontal axis.
C
      WRITE (*,945)
 945 FORMAT (10X,'-+-------+-------+-------+----',
     +'---+-------+-------+-------+----')
      DX=(XMAX-XMIN)/8.0D0
      DO 950 I=1,9
        X(I)=XMIN+DBLE(I-1)*DX
 950 CONTINUE
C
      WRITE (*,960) (X(I),I=1,9)
 960 FORMAT(7X,9(F6.1,2X),'X')
C
      CALL PAUSE
C
      RETURN
      END
C
C
C-----------------------------------------------------
C
      SUBROUTINE WRLINE(LINES)
C
      INTEGER LINES
C
      DO 3010 I=1,LINES
        WRITE(*,3000)
 3000   FORMAT(' ')
 3010 CONTINUE
C
      RETURN
      END
C
C
C-----------------------------------------------------
```